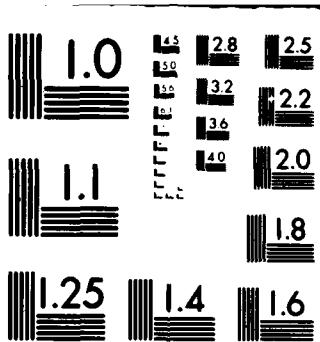


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CONTAMINANT INCREASE IN AIRCRAFT LIQUID OXYGEN CONVERTERS; ANAL--ETC(U)
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Report SFQ-TR-80-1

CONTAMINANT INCREASE IN AIRCRAFT LIQUID OXYGEN CONVERTERS

Analysis of Data

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San Antonio ALC/SFQT
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August 1980

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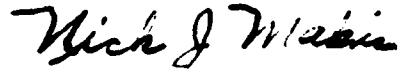
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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER SFQ-TR-80-1	2. GOVT ACCESSION NO. AD-A090975	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) CONTAMINANT INCREASE IN AIRCRAFT LIQUID OXYGEN CONVERTERS; Analysis of Data	5. TYPE OF REPORT & PERIOD COVERED Rept. for Mar 1979 - May 1979	
7. AUTHOR(s) 10. Lester L. Dziuk	6. PERFORMING ORG. REPORT NUMBER 12/22	
9. PERFORMING ORGANIZATION NAME AND ADDRESS San Antonio ALC/SFQT Kelly AFB TX 78241	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS	
11. CONTROLLING OFFICE NAME AND ADDRESS 14. SAA LC/SFQT-80-1	12. REPORT DATE Aug 1980	
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	13. NUMBER OF PAGES 14	
15. SECURITY CLASS. (of this report) Unclassified		
15a. DECLASSIFICATION/DOWNGRADING SCHEDULE		
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Oxygen, Aircraft Converter, Contaminants, Evaporation		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Analysis of data collected during a study of contaminant buildup in an aircraft liquid oxygen converter is presented. The data indicates that contaminants increase during the interval between fillings and that contaminants are removed during fillings. No overall trend of contaminant increase was observed.		
NLL 412000		

ACKNOWLEDGMENTS

The assistance of Mr Eugene L. Taylor of the Aerospace Fuels Laboratory, MacDill AFB FL, who provided the data used in this analysis is hereby acknowledged.

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INTRODUCTION

Liquid oxygen in aircraft life support systems is often suspected as a possible cause of physiological incidents. This is because liquid oxygen becomes enriched in contaminants as it evaporates due to its higher vapor pressure. Contaminants are present in liquid oxygen due to purification limits of the process of manufacture and due, in some instances, to their introduction during transfers. Thus the physical properties of liquid oxygen suggest that contaminant buildup is possible, if not likely. Laboratory analysis of liquid oxygen samples taken from converters of twenty two operational aircraft resulted in contaminant levels which failed requirements for storage tanks in only three of the converters.^{1, 2} (Acceptable contaminant levels have not been established for converters because samples are not routinely drawn from them.) The results were not unexpected considering transfers during the servicing process and the higher evaporation rate of converters which favor contaminant increase.

The existence and nature of contaminant trends in converters of operational aircraft are difficult to determine due to the irregular exchange of liquid oxygen which results from varying schedules of pilot demand and converter

¹ Taylor, E. L., "Analysis of ABO from Aircraft Converters," SFQLC Technical Report on SFQL Project 77-3, 18 May 1977.

² "Quality Control of Oxygen Propellant Liquid Oxygen, Aviator's Liquid Breathing Oxygen, and Aviator's Gaseous Breathing Oxygen." TO 42B6-1-1, 31 Jan 77

servicing. (During operation, demand placed on the converter by a pilot results in liquid oxygen being drawn from the converter to be subsequently vaporized for respiration. Liquid oxygen is replaced by servicing the converter as required.) The difficulty is compounded by the unknown level of contaminants in the oxygen serviced to the aircraft. Though storage tanks are analyzed periodically, the servicing trailers used are not. Also the liquid oxygen in a converter is not readily traceable to the trailer used to service it.

A study was planned in which variables affecting contaminant trends could be measured and controlled so that some insight into such processes might be gained. At that time the contaminant levels in the converter were considered to be solely dependent upon the addition of contaminants with the servicing of oxygen, concentration of contaminants caused by selective evaporation, and removal of contaminants by placing a demand for liquid oxygen on the converter. By effectively eliminating demand, one of the processes which removes contaminants, it was thought that a worst case for contaminant levels could be studied. Accordingly, a study was performed by the Aerospace Fuels Laboratory at MacDill AFB FL in which a converter kept in the laboratory was periodically analyzed for contaminants. Additions were made on a regular basis with liquid oxygen of known contaminant concentrations. No demand was placed on the converter other than that of sampling. The following paragraphs present some observations and analysis of this study.

EXPERIMENTAL

A 10 liter capacity aircraft converter was used in this study. It was kept in the laboratory except when taken to the storage tank for filling. No demand was placed on the converter except for the small amount drawn for analysis. The duration of the study was approximately 5 weeks. During this time the converter was filled with liquid oxygen on Mondays and Fridays and was never allowed to become empty. The converter was weighed and samples drawn from it each day except Saturday and Sunday. Samples were also drawn before and after filling on Mondays and Fridays. Converter samples were drawn from the line which would normally supply the aircraft system. The storage tank was sampled following each filling of the converter. Samples were analyzed using an infrared spectrophotometer.

LINEAR REGRESSION CONTAMINANT INCREASE

Data was analyzed using the method of least squares. Data points analyzed are shown in Figures 1, 2, and 3. The expression $C = aV^{-b}$ was used in the analysis. C is the concentration of the contaminant, V is the volume of liquid oxygen, and a and b are constants. The constant a represents the concentration of the contaminant when 1 liter of oxygen remains. It is dependent upon the initial concentration. The numerical value of the constant b is an indication of the volatility of the contaminant and is dependent on the contaminant analyzed. A value of $b = 1$ indicates that all the contaminant remains in the liquid phase and none is lost through vaporization. Decreasing values of b relate to increasing volatility of the contaminant.

The data on carbon dioxide is presented differently than that of methane and Freon 13 because the values were much more random and one set of data was not readily distinguished from another. Sets of data from single fillings of the converter which resulted in 5 data points were analyzed and the following equations resulted.

$$26 \text{ Mar 79: } C = 1.017 V^{-0.2489}$$

$$2 \text{ Apr 79: } C = 2.036 V^{-0.9940}$$

$$9 \text{ Apr 79: } C = 6.303 V^{-1.102}$$

$$16 \text{ Apr 79: } C = 7.286 V^{-1.623}$$

$$23 \text{ Apr 79: } C = 3.865 V^{-1.741}$$

All data points shown in Figure 3 were analyzed and the following equation resulted: $C = 2.678 V^{-1.135}$

The dashed lines illustrate the limits of prediction. We can say with a probability of 0.99 that if another sample had been drawn and analyzed during the study, the carbon dioxide value would be within the limits described by the dashed lines.

LINEAR REGRESSION EVAPORATION RATE

The data analyzed for contaminant increase in Figures 1 and 2 was also analyzed for evaporation rate. Data and results are shown in Figure 4. Values for day 0 were not included in the analysis because apparently the converter was not at thermal equilibrium. The expression $V = et + f$ was used in the analysis. V is volume in liters, t is time in days, and e and f are constants. The constant e represents the evaporation rate. The constant f represents what would have been the initial volume if oxygen had been added which was in thermal equilibrium with the converter.

MATHEMATICAL EXPRESSION

If it is assumed that the rate of contaminant loss due to normal evaporation in liquid oxygen is directly proportional to its concentration, then

$$\frac{dq}{dt} = k_1 C \quad (1)$$

The total quantity (q) of contaminant lost is related to its concentration and the volume of liquid oxygen.

$$q = C_0 V_0 - CV \quad (2)$$

Differentiation of (2) yields

$$dq = - CdV - VdC \quad (3)$$

If it is assumed that the rate of loss of liquid oxygen from a system in an environment with stable conditions is constant, then

$$\frac{dV}{dt} = \frac{1}{k_2}$$

$$dt = k_2 dV \quad (4)$$

Substitution of (3) and (4) into (1) yields

$$\frac{- CdV - VdC}{k_2 dV} = k_1 C \quad (5)$$

Separation of variables yields

$$\frac{dC}{(k_1 k_2 + 1) C} = \frac{dV}{V} \quad (6)$$

Integration yields

$$\ln C = - (k_1 k_2 + 1)^{-1} \ln V + \ln a \quad (7)$$

which may be written

$$C = aV^{-b} \quad (8)$$

where

$$b = (k_1 k_2 + 1)^{-1}$$

DISCUSSION

Contaminants such as methane, Freon 13, and probably carbon dioxide increase in concentration during dormant storage as described by equation (8). The b values of greater than 1 for Freon 13 and carbon dioxide were puzzling. They indicated that the total quantity of contaminants in the converter increased during the dormant period. The value for Freon 13 may be a result of the low levels of the contaminant analyzed. The value for carbon dioxide as well as the randomness of the data may be a result of the proximity to the solubility limit.

Contaminants were expected to increase during the 5 weeks of the study because of the "no demand" condition placed on the converter. The preferential evaporation of oxygen was to cause contaminants to accumulate. This did not occur. Data showing the total quantity of contaminant in the converter was plotted along with data showing the concentration of contaminant in the storage tank. See Figure 5 and 6. The contaminants in the converter decreased following addition of better quality product to the storage tank between 2 and 6 April. This unexpected result was probably due to the effect shown in Figure 7. Apparently some purging of the converter occurs during filling. The curve charts weight of oxygen in the converter vs the elapsed time of filling. The purging effect may be explained by the fact that the converter is maintained at a higher pressure (70-90 psig) than the storage tank (30-35 psig). These pressures equate to equilibrium temperatures of about -256°F for the converter and about -275°F for the storage tank - a difference of 19°F . Additionally, the vent

valve of the converter is open during filling which means that the liquid oxygen will boil away to attain its boiling temperature at atmospheric pressure or -298°F. Figure 4 demonstrates that the converter was below its equilibrium temperature after filling - the loss of oxygen between day 0 and day 1 was much less than the rate during the remaining days. The incoming colder liquid oxygen and the boiling necessary to attain temperature relative to atmospheric pressure must cause conditions which remove high boiling contaminants at a higher rate than expected.

FUTURE WORK

- a. More significant data may be obtained by repeating this study with liquid oxygen which has higher levels of contaminants - especially those with a b value near 1. The data of Figures 5 and 6 show that the Freon 13 did not decrease to a steady state as the methane did following the filling of the storage tank. This suggests a lesser tendency for Freon 13 to be purged from the converter. However, the level of Freon contamination was so low that it is difficult to place much significance on this data. It would be appropriate to develop data on this and other high boiling contaminants nearer established use limit values.
- b. A similar study should be accomplished on a liquid oxygen servicing trailer used to service aircraft converters. These trailers are stored at atmospheric pressure and should not demonstrate the same purging effect seen in the converter. Such a study would determine the need for quality control requirements on these trailers.

Figure 1

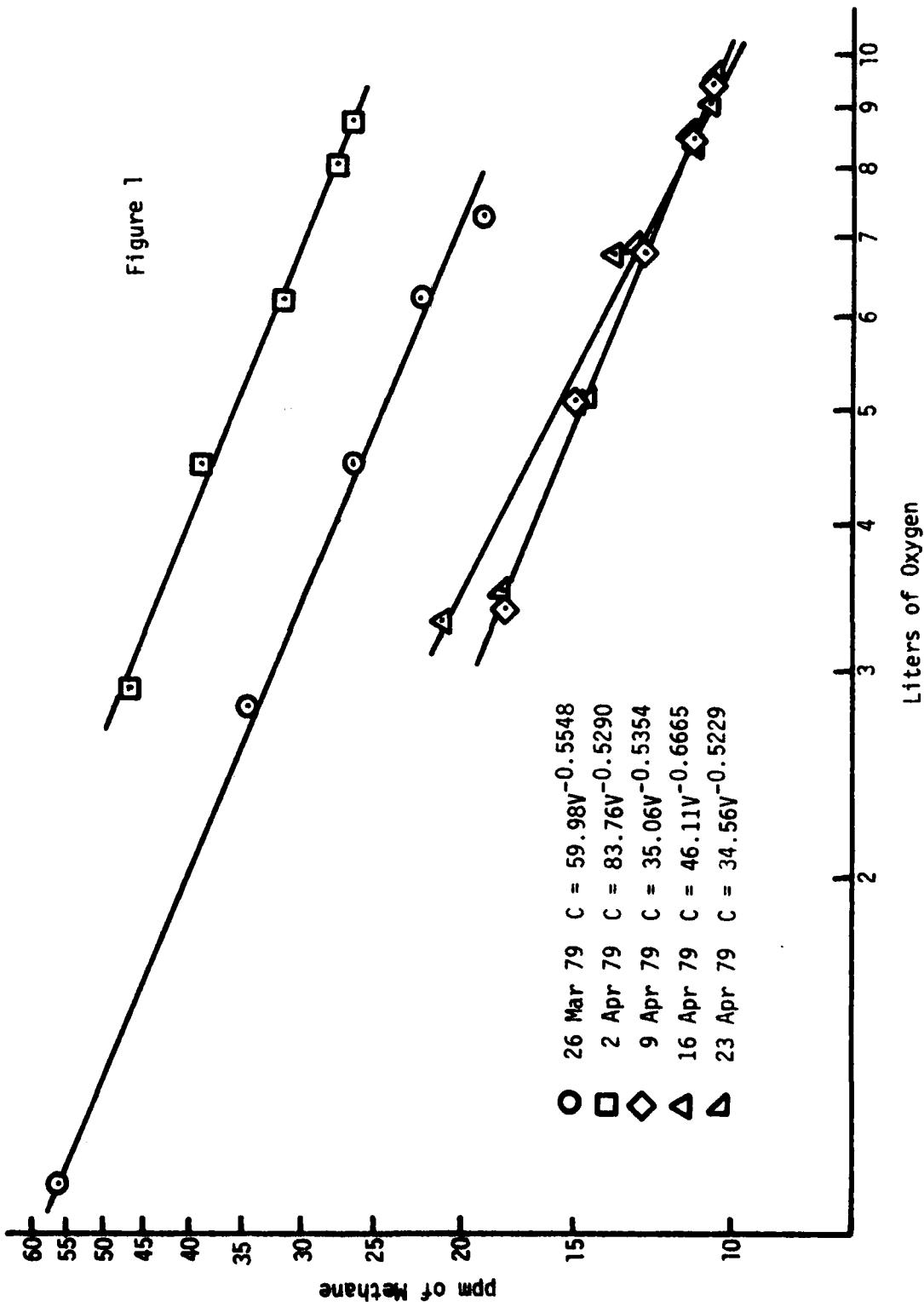


Figure 2

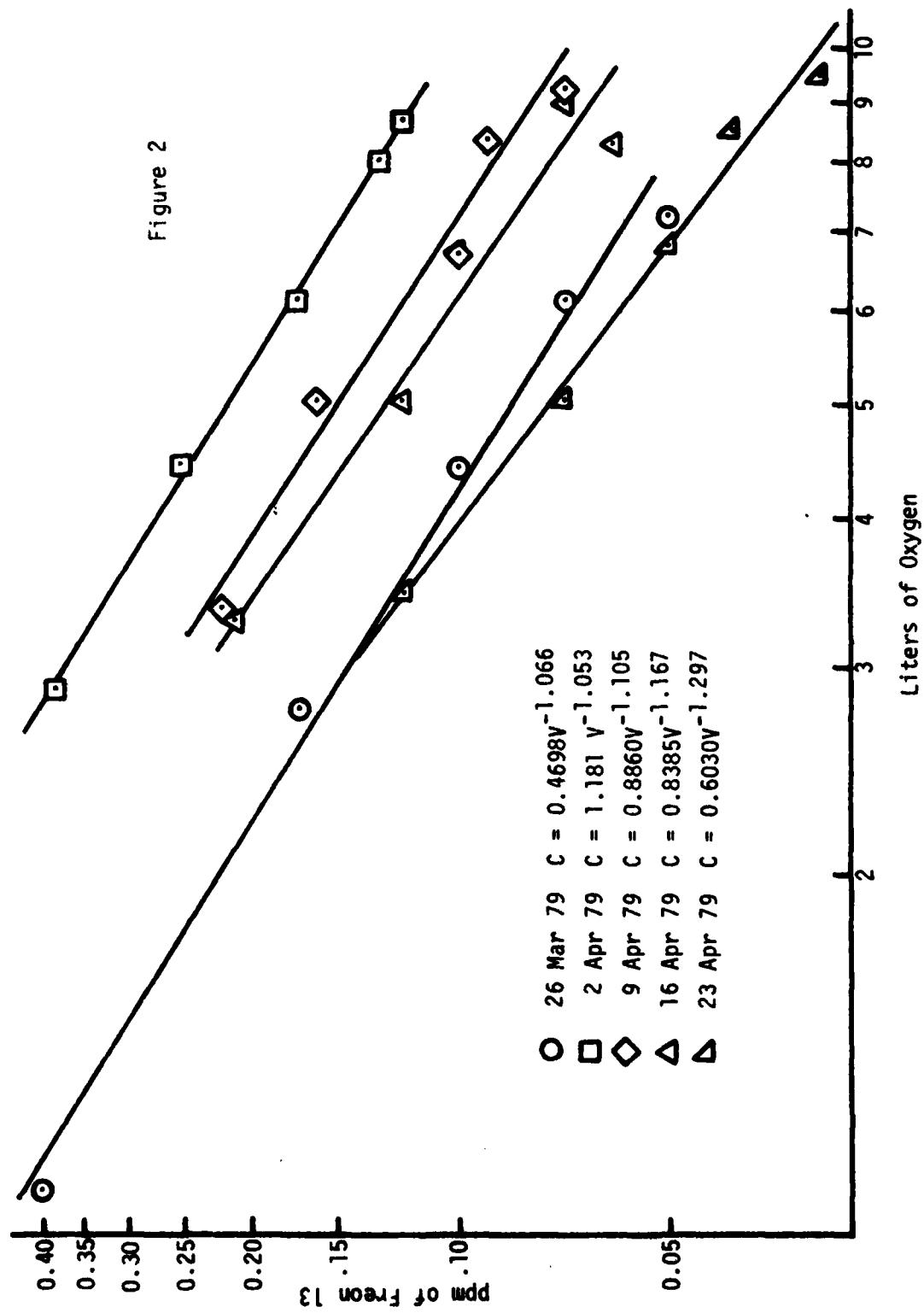


Figure 3

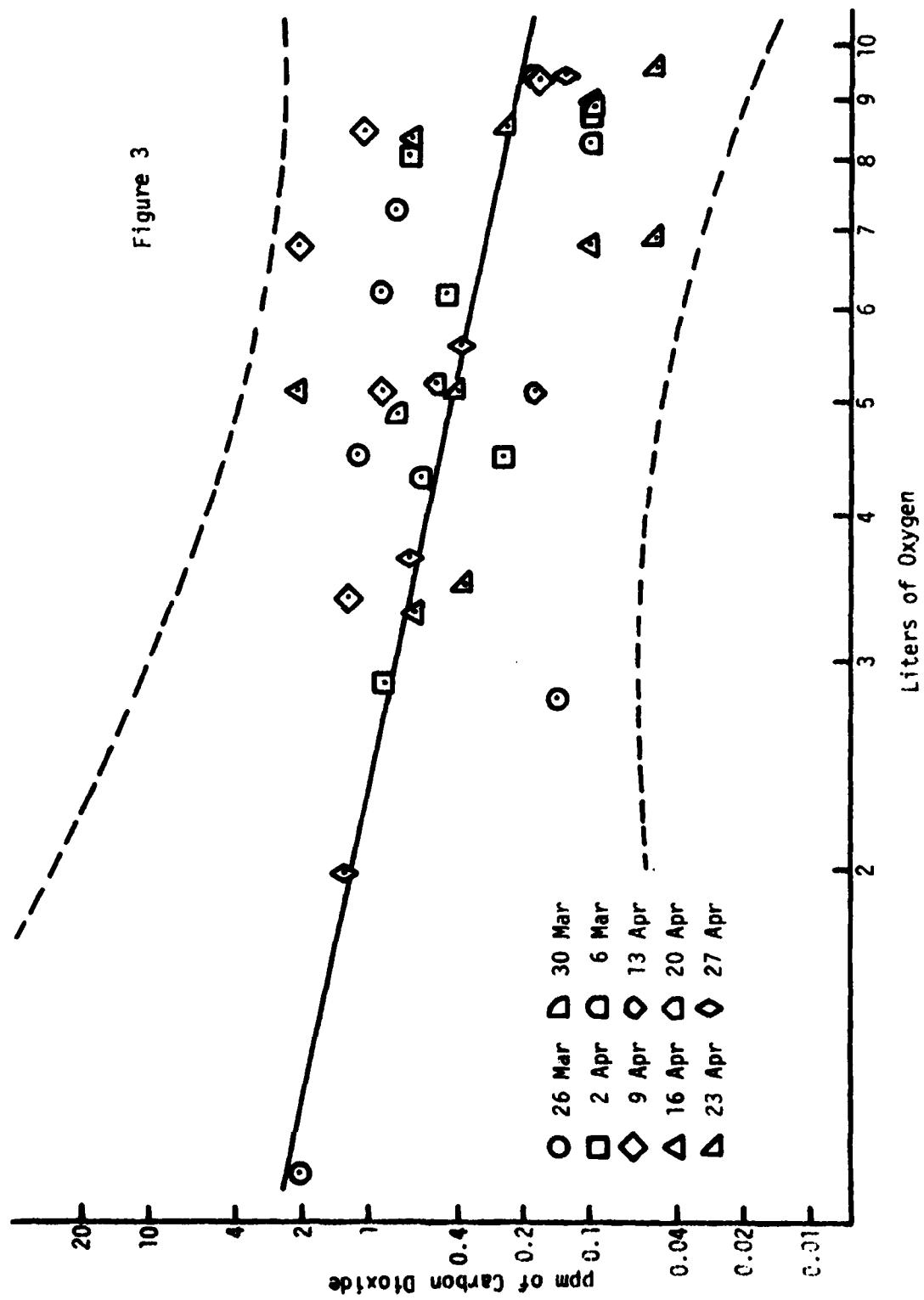
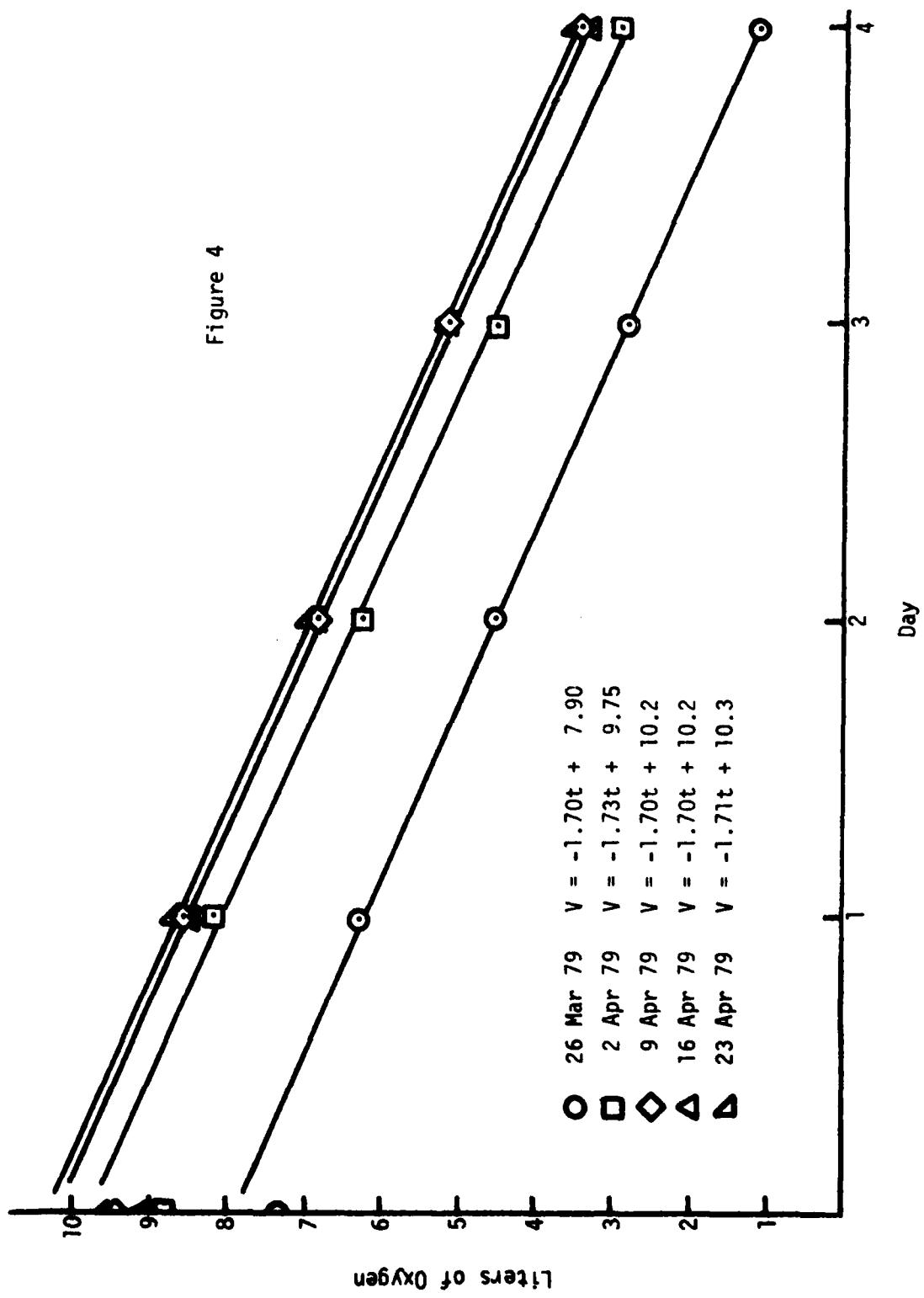
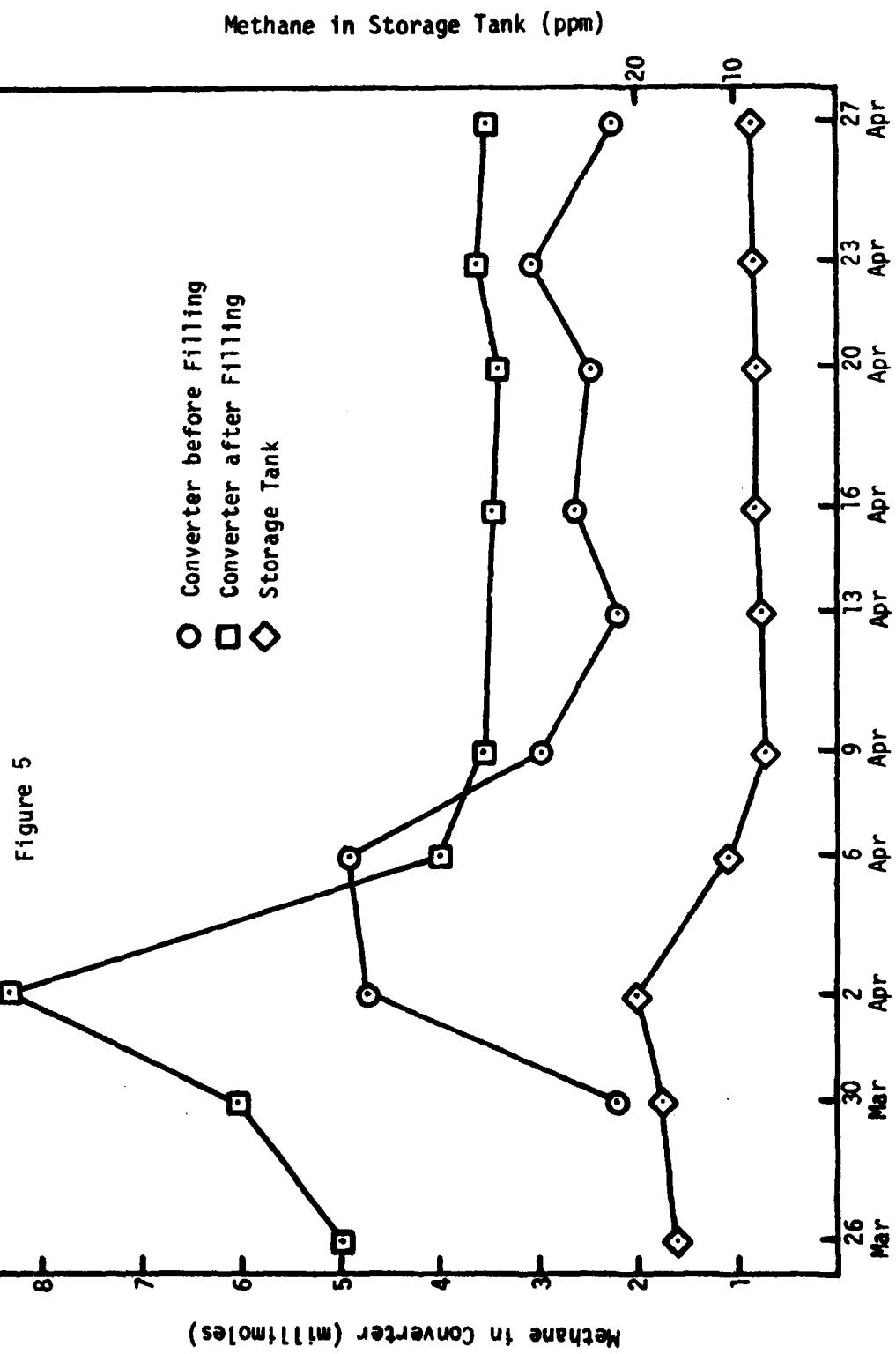
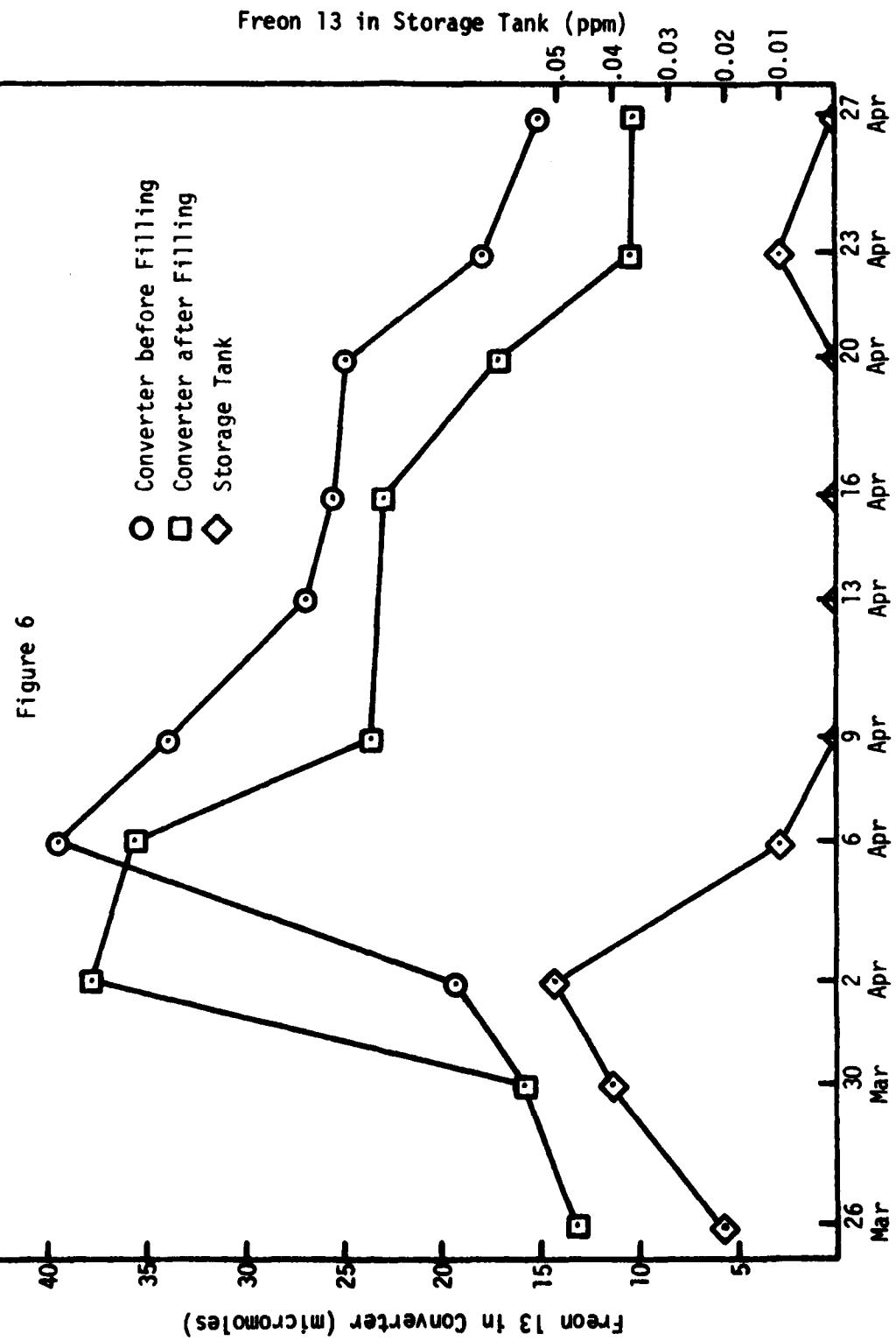
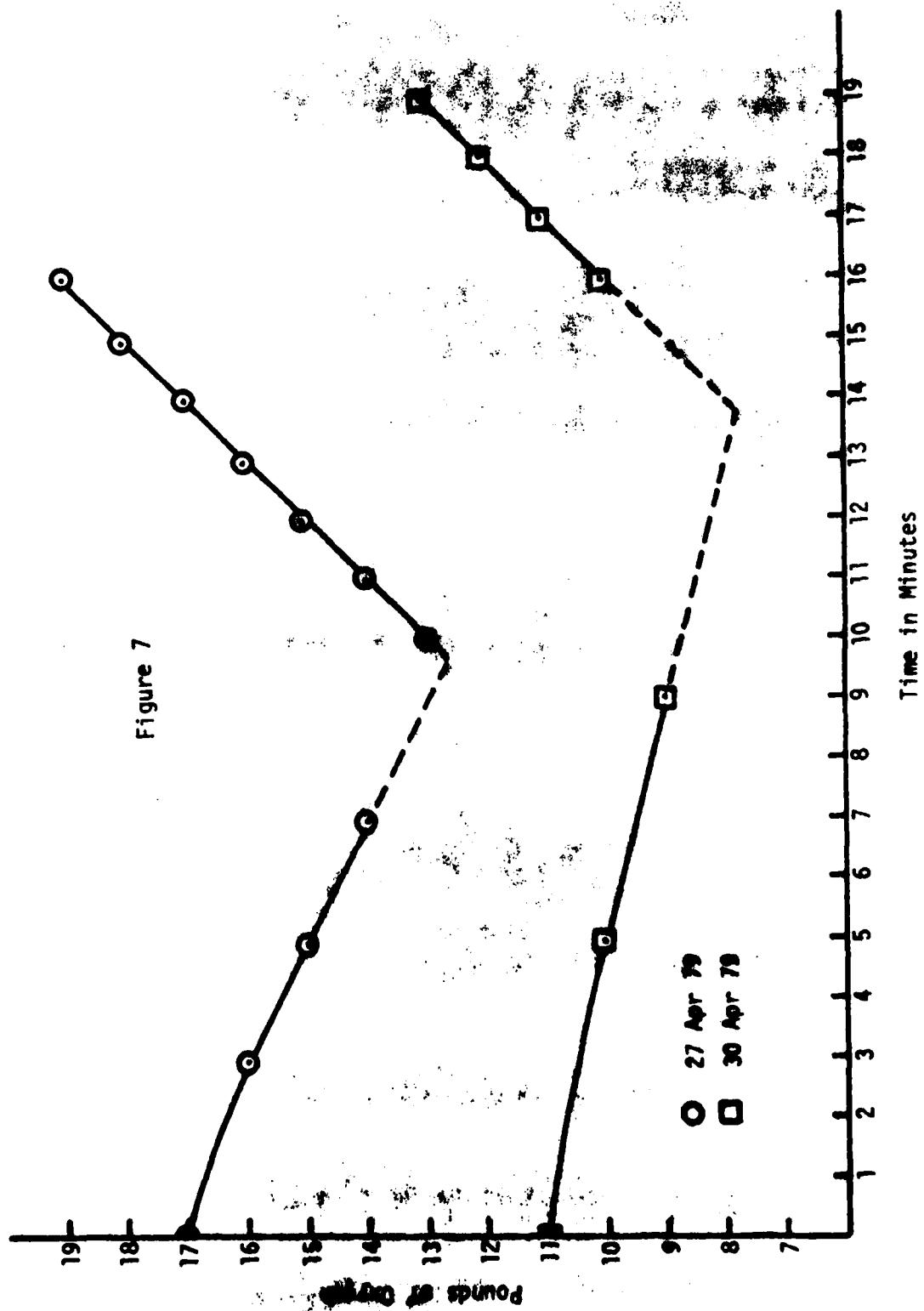


Figure 4









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